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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN OR RELATING TO DEVICES FOR USE IN PRODUCING X-RAY PHOTOGRAPHS

(71) I, IRMGARD FISCHER, trading as IRMGARD FISCHER-ELEKTRONIK KONSTRUKTIONSBÜRO U. WERKSTÄTTEN FÜR ELEKTRO- u. VAKUUMTECHNIK, and being a German citizen, of Feldbergstrasse 1, 7801 Vörstetten, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to devices for use in producing X-ray photographs, particularly dental X-ray photographs.

The invention is particularly concerned with devices for use in producing dental X-ray photographs which make use of special hollow-anode X-ray tubes which are quite distinct in construction and function from the usual diagnostic X-ray tubes.

In the presently known tubes of this hollow-anode type, the whole electrode system—comprising a cathode emitting the electrons, a control electrode affecting the focussing, and a usually conical anode arranged in the anode tube with a collecting or focussing coil mounted on the anode tube and also affecting the focussing of the electron stream—is so constructed that it is formed from two or three mechanically completely separate electrode units as far as adjustment of the system is concerned. In these hollow-anode X-ray tubes the focal spot is created at the end of a hollow-anode tube outside the actual X-ray tube casing holding the cathode and with a conical anode it is at the cone tip pointing towards the cathode.

In the X-ray tubes used in dental medical diagnostic treatment for producing full-mouth or panoramic photographs, in which the anode tube is introduced into the mouth, the focal spot of the tube must be kept very small on account of the comparatively small focal length necessitated by these photographic techniques and on account of the lack of sharpness in the image which would otherwise arise, with the result that the electrode system of such a tube must be extremely acurately focussed and adjusted initially and must then remain so. The danger of the tube becoming out of adjustment is greater the smaller the diameter of the anode tube and the more delicate the electrode system of the X-ray tube.

Since the wall thickness of the hollow-anode tube, which is barely the size of a finger in diameter, must be kept small and since the electron stream must be very accurately adjusted because of the comparatively small focal spot, the user of such tubes protects the very highly sensitive anode tube, which is formed from very soft annealed copper at those places where in the event of a mechanical stress the greatest bending moment is exerted, by placing a protective cap over the tube housing in the inactive position of the device to protect the anode tube from damage and defocussing. When preparing the instrument for use and when actually using the instrument the protective cap is removed in all cases.

It is an object of the present invention to provide an X-ray device, comprising a hollow-anode X-ray tube mounted in a housing and provided with an anode tube projecting from the housing, which is resistant to inadvertently applied stresses acting in the device and which is also protected against defocussing and movement out of adjustment.

In accordance with the present invention there is provided a device for use in the production of X-ray photographs comprising a hollow-anode X-ray tube mounted in a housing and including a casing within the housing and an anode tube projecting from the housing, mounting means rigidly connected to the tube casing, and resilient sup-

port means connected to said mounting means, said resilient support means being secured to the housing to provide a resilient connection between the housing and the casing of the hollow-anode X-ray tube.

In this way, in the event of a blow on the anode tube, this tube together with the whole X-ray tube and the focussing means rigidly connected thereto together yield to the blow, and then return to the positions occupied before the blow took place, so that in consequence the adjustment of the focussing is not adversely affected.

In the X-ray device of the present invention the X-ray tube casing including the part of the anode tube adjacent to the cathode is preferably formed of a ceramic material, preferably an oxide, since this provides the anode tube with a substantially higher resistance to bending stresses than the copper components previously generally used.

Since the thickness of the objects in the whole of the irradiated field of interest for full-mouth photography is approximately the same, it is of great importance that any prefiltering of the radiation within the radiation beam angle should be constant. This is not the case in the presently known hollow-anode constructions in which the anode tubes and/or the applicators placed over the tubes have a constant wall thickness in the vicinity of the source of the emitted radiation, with the result that the X-rays follow different length paths in their passage through the wall in dependence on the angle at which they are emitted and are consequently subjected to differential filtering. This disadvantage is overcome in accordance with a preferred feature of the present invention by the provision of prefiltering material at the head of the anode tube containing the anode, the distribution being such that uniform prefiltering of the radiation occurs over the whole beam angle necessary for full-mouth examination. This may be achieved by making the wall at the head of the anode tube of non-uniform thickness such that all X-rays passing through the tube wall at whatever angle traverse equal length paths through the tube wall. Alternatively, it is possible to provide additional prefiltering material on the head of the anode tube in addition to the actual tube material, this additional prefiltering material being provided in such a way that the X-rays which on the basis of their angle of emission traverse a shorter path length through the tube wall pass through a greater mass of prefiltering material than the X-rays which traverse a longer path length.

In photographing the upper jaw it is sometimes necessary in special cases to provide a cut-out in the film strip for the nose of the patient and to photograph the unphotographed nose part in the usual manner, i.e. with the film inside the mouth and with the X-ray tube outside the mouth. The presently known hollow-anode X-ray tubes cannot be used in this way. Photographic views of the whole jaw region are produced with the presently known hollow-anode X-ray tubes when inserted into the mouth for dental X-ray photographs, and these overall pictures obviously give information about the general status of the teeth. However, with these X-ray photographs one takes photographs of the whole of one or both jaws from one focal spot position, which automatically means that individual teeth or whole groups of teeth are shown heavily distorted on the X-ray film relative to their anatomically correct images or positions in the jaw. Because of this, for specific diagnosis of individual teeth it is necessary to take individual photographs of teeth or groups of teeth by the distortion free intra-oral or extra-oral techniques which are presently known. In order to carry out these two basically different photographic techniques the dental practitioner must at present have two different X-ray machines respectively adapted for the separate photographic techniques and with which one has to use X-ray tubes which are likewise different and adapted respectively for the differing photographic techniques.

It is therefore extremely desirable to provide a device equipped with a hollow-anode X-ray tube which is also such that distortion free photographs of individual objects can be achieved with it as with the known intra-oral and extra-oral photographic techniques. This is achieved with a preferred form of the invention by providing a second X-ray tube within the housing of the device and in addition to the hollow-anode X-ray tube, the direction of emission of radiation from the second tube being at an angle of substantially 90° to the longitudinal axis of the hollow-anode X-ray tube. A high voltage transformer for both tubes is preferably also mounted within the housing of the device so that in this case the device can be described as a one-piece instrument.

Instead of having two separate X-ray tubes at is alternatively possible to use a double X-ray tube suitable both for full-mouth photography and also for intra- and extra-oral photography, such double X-ray tube having two separate cathode filaments in a common casing. This results in a system which can be made extremely compact. On the other hand, a device using two separate X-ray tubes has the possible advantage that the X-ray tubes may be of a simpler and cheaper construction and that in the event of failure of one complete X-

ray system or one X-ray tube the other X-ray system is still usable until replacement or repair of the failed system or tube. When using a common tube casing for both X-ray systems the casing may be secured to mounting means which includes an X-ray target in alignment with the cathode filament for the said second X-ray tube and a side window through which X-rays from the target are beamed.

In order that the invention may be more fully understood a number of embodiments in accordance therewith will now be described by way of example and with reference to the accompanying drawings, in which:

Fig. 1 is a cross-sectional view through a part of a first embodiment of a device in accordance with the invention, the device comprising a hollow-anode X-ray tube, here shown in its inactive position;

Fig. 2 is a similar cross-sectional view of the device shown in Fig. 1 but with the hollow-anode X-ray tube in its operational position;

Fig. 3 is a similar cross-sectional view through a second embodiment of a device in accordance with the invention, this device comprising a double X-ray tube adapted both for panoramic full-mouth photography and also for intra-oral and extra-oral photography, and with the device here shown in its operational position for the last-mentioned photographic technique;

Fig. 4 is a longitudinal sectional view through the head of the anode tube of a hollow-anode X-ray tube, the upper half (A) of the illustrated tube being of known form and the lower half (B) of the illustrated tube being of modified novel form;

Fig. 5 is a longitudinal sectional view through the head of the hollow-anode X-ray tube illustrating the radiation beam-angle necessary for panoramic full-mouth examination and of interest in relation to prefiltering considerations;

Fig. 6 is a schematic longitudinal sectional view through a third embodiment of a device in accordance with the invention, the device here comprising two separate X-ray tube systems;

Fig. 7 is a front end elevational view of the device of Fig. 6;

Fig. 8 is a schematic longitudinal sectional view through a fourth embodiment of a device in accordance with the invention, again comprising two separate X-ray tube systems; and

Fig. 9 is a front end elevational view of the device of Fig. 8.

In the embodiment of the device shown in Fig. 1 the X-ray tube comprises a casing 16 fitted with an anode tube 9 carrying a conical anode 17; a mount 1 at anode potential and rigidly connected to the tube casing 16; and a focussing unit 5 which is fixedly connected to the tube system. The mount 1 is connected to a housing 4 of the device by means of a resilient link 2, for example in the form of a spring element. A high voltage generator (not shown) for the X-ray tube is mounted in a suitable manner within the housing 4 of the device.

In spite of the provision of a resilient supporting link 2 it is important to provide additional protection for the exposed comparatively slender anode tube 9 in its inactive position. For this purpose a protecting tube 15 is provided which is secured so as to be displaceable in the axial direction over the housing 4 of the device. In Fig. 1, this protecting tube 15 is shown in its operative protective position enclosing the anode tube 9. The tube 15 is provided with an aperture 18 in its end face to provide for passage of the anode tube 9 therethrough.

Additional springs 7 are provided between the housing 4 and the mount 1 on the tube casing 16 in order to adjust the flexibility and resiliency of the link 2 so that it will absorb forces arising as a result of impacts or pressures on the anode tube 9 and will return the tube system to its original setting as soon as such foreign external forces no longer act on the anode tube.

In the illustration shown in Fig. 2 the protecting tube 15 has been withdrawn back over the housing 4 of the device so that the anode tube 9 is located in its operational position in which it can be inserted into the mouth if panoramic photography of the whole of a patient's mouth is to be carried out.

The embodiment of the invention which is shown in Fig. 3 comprises a double X-ray tube by means of which it is possible to use both the hollow-anode technique for panoramic full-mouth photography and also intra-oral and extra-oral photographic techniques for examination of individual teeth. In this embodiment a tube side window 11 with an electron target disc 10 arranged adjacent thereto are provided in the mount 1 as a part of the tube casing 16, in addition to the anode tube 9 which has the anode 17 as an electron target point. A filament arrangement 13 acting as the cathode associated with the anode 17 and a filament arrangement 14 acting as the cathode associated with the electron target disc 10 are provided within the tube casing 16. The mount 1 is at anode potential.

In this embodiment the cathode filaments 13 and 14 which are necessary for the two electrode systems are mounted on a cathode support 12 and can be selectively switched on individually according to the desired type of photographic examination to be effected with the device.

In this embodiment, apertures are provided in the housing 4 and in the axially displaceable protecting tube 15 for the passage of the X-rays emitted through the tube side window 11. These apertures are so arranged that when the device is used for hollow-anode photographic examination the protecting tube 15 masks the aperture in the housing 4 in front of the side window 11 and uncovers the free end of the anode tube 9, while when the device is used for intra-oral or extra-oral photographic examination the protecting tube 15 encloses the free end of the anode tube 9 and unmasks the side window 11.

The upper half of Fig. 4 of the drawings, designated as A, shows the head of a known form of hollow-anode X-ray tube in which the anode tube 9 is cylindrical and of uniform wall thickness in the radiating region. In such circumstances the X-rays coming from the anode 17 within a beam angle α and which do not pass through the wall of the anode tube at right-angles along the line S, for example rays passing along the lines S1 to S4, must penetrate larger amounts of the material of the anode tube. These rays are therefore prefiltered differentially and this has an extremely unfavourable effect on the quality of the image on the X-ray photograph.

In the lower half of Fig. 4, designated as B, there is there shown how this differential prefiltering of the X-rays is avoided by the use of a special configuration for the wall thickness of the head of the anode tube 9. With the wall thickness made non-uniform as shown the same length of path S is traversed by all radiation from the anode 17 throughout the whole beam angle which is of interest.

Fig. 5 shows, in relation to an anode tube 9 with a conical anode 17 and fitted with an applicator 8 over the anode tube, the tube and applicator being shown inserted into a patient's mouth, that the beam angle α shown in Fig. 4 is in fact necessary for full-mouth photographic examination.

Alternatively, it is possible to provide additional prefiltering material on the head of the anode tube 9, preferably on its external surface, with such a distribution or gradation that the X-rays within the beam angle α which follow a shorter path through the wall of the head of the tube traverse a greater mass of prefiltering material than the X-rays which follow a longer path. In this case, the cylindrical wall of the anode tube, as is shown in the upper part A of Fig. 4, may have its thickness unchanged. Alternatively, this additional prefiltering material may be provided on the applicator 8 which is slidable over the anode tube 9, or it may be provided partially on this applicator and partially on the anode tube itself. By these means one can ensure in a simple manner that all the X-rays coming from the anode 17 are prefiltered to the same extent irrespective of their direction, and preferably to a degree equivalent to the case of the rays taking the longest path S4.

The X-ray tube casing, including the part of the anode tube adjacent to the cathode, is preferably made from a ceramic material having high resistance to bending stresses. Among the best materials are ceramic oxides, particularly beryllium oxide, which can absorb large bending moments and which at the same time are permeable to the magnetic field necessary for focussing the electron stream.

In each of the embodiments described above in which the mounting of the X-ray tube within the housing of the device is accomplished by means of an intermediate element such as the resilient link 2, this resilient supporting link need not necessarily consist of a spring element, but for example can alternatively be in the form of resilient membranes, or in the form of ball and socket joints in association with individual springs spaced on a circle around the tube. In each case the arrangement is such that the reaction of the resilient link to bending stresses due to forces acting from externally on the anode tube 9 is smaller than the reaction to deformation of the anode tube 9 due to the external forces acting thereon.

The focussing unit 5 shown in Figs. 1 to 3 may be an electromagnetic unit of a permanent magnet system. It will further be appreciated that an electrostatic focussing unit could alternatively be used.

In the embodiment shown in Figs. 6 and 7 there is provided a hollow-anode X-ray tube suitable for panoramic full-mouth photographic examination and comprising the X-ray tube casing 16, the anode tube 9, and an associated transformer 6 mounted on an axis 19 which is parallel to but displaced upwardly relative to the longitudinal axis 20 of the housing 4 of the device. Parallel to this tube 9, 16 is provided an intra-oral tube 21 having its longitudinal axis 22 displaced downwardly relative to the longitudinal axis 20 of the housing 4 of the device. The direction 23 of the emitted radiation from the intra-oral X-ray tube 21 is at 90° to the longitudinal axis 19 of the hollow-anode X-ray tube 9, 16.

In this embodiment the hollow-anode X-ray tube 9, 16 is resiliently mounted in the housing 4 by means of springs or a spring bellows or a membrane 2. A protecting tube 15 is provided to protect the anode tube 9. The protecting tube 15 is displaceable along the axis of the X-ray tube such that its cylindrical wall is displaceably positioned within the housing 4 and only its forward end wall portion provided with an aperture

25 for the anode tube 9 lies outside the housing 4. A window 24 for the passage of radiation from the intra-oral tube 21 is provided in the cylindrical wall portion of the protecting tube 15. This window 24 is only aligned with the output from the intra-oral tube 21 when the hollow-anode X-ray tube 9, 16 is not operational and is enclosed by the protecting tube 15. However, the window 24 is not in alignment with the axis 23 of the radiation from the tube 21 when the protecting tube 15 is displaced inwardly and the hollow-anode X-ray tube 9 extends in its operative position.

The embodiment illustrated in Figs. 8 and 9 only differs from that shown in Figs. 6 and 7 in that the two X-ray tubes 9, 16 and 21 are not arranged one below the other but are positioned on a common axis 22 one behind the other within the housing 3. In this embodiment the housing 3 is not cylindrical but has an inverted teardrop shape cross-section. The hollow-anode X-ray tube is mounted within the housing 3 in almost the same way as in the embodiment shown in Figs. 6 and 7 but below the pivot axis 20 of the housing, while the second X-ray tube 21 lies on the axis 22 behind the hollow-anode X-ray tube 9, 16. The two transformers 6 and 26 of these two X-ray systems are provided as a one-piece unit, and in the embodiment of Figs. 8 and 9 are positioned within the upper portion of the housing which is of larger cross-section.

In both the embodiments shown in Figs. 6 to 9 the direction 23 of the emitted radiation from the intra-oral tube 21 makes an angle of 90° with the longitudinal axis 19 of the hollow-anode X-ray tube 9, 16.

Although the two tubes 9, 16 and 21 are shown in Figs. 6 to 9 with their longitudinal axes parallel to each other it is possible to arrange the X-ray tube 21 for example with its longitudinal axis at an angle to the longitudinal axis of the tube 9, 16. This may be done for example simply by turning the tube 21 through 90° from the position shown in Figs. 6 to 9 while maintaining its axis in the same horizontal plane.

The casing of the intra-oral or extra-oral X-ray tube 21 preferably consists of a ceramic oxide with the tube side window being formed from sintered beryllium oxide.

WHAT WE CLAIM IS:—

1. A device for use in the production of X-ray photographs comprising a hollow-anode X-ray tube mounted in a housing and including a casing within the housing and an anode tube projecting from the housing, mounting means rigidly connected to the tube casing, and resilient support means connected to said mounting means, said resilient support means being secured to the housing to provide a resilient connection between the housing and the casing of the hollow-anode X-ray tube.

2. A device as claimed in claim 1, in which the resilient support means comprises at least one spring body.

3. A device as claimed in claim 1, in which the resilient support means comprises at least one flexible membrane.

4. A device as claimed in claim 1, in which the resilient support means comprises ball and socket joints in combination with a plurality of springs.

5. A device as claimed in any preceding claim, which includes spring means seated against said housing and acting to bias said mounting means and the hollow-anode X-ray tube to a predetermined position.

6. A device as claimed in any preceding claim, which includes a protecting tube for the anode tube, said protecting tube being displaceable relative to the housing and in the axial direction of the anode tube in such manner that in a first, extended position it encloses the anode tube while in a second, withdrawn position the anode tube projects outwardly through an aperture provided in the protecting tube.

7. A device as claimed in any preceding claim, which includes a second X-ray tube provided in the housing, said second X-ray tube being mounted to direct its emitted X-rays at an angle of substantially 90° to the longitudinal axis of the hollow-anode X-ray tube.

8. A device as claimed in claim 7, in which the hollow-anode X-ray tube is mounted with its longitudinal axis coaxial with the longitudinal axis of said housing or on an axis parallel thereto, and said second X-ray tube is offset laterally relative to the hollow-anode X-ray tube.

9. A device as claimed in claim 7, in which said second X-ray tube is arranged within said housing with its longitudinal axis on the axis of said hollow-anode X-ray tube but positioned behind said latter tube.

10. A device as claimed in claim 7, in which said second X-ray tube is arranged with its longitudinal axis at an angle to the longitudinal axis of the hollow-anode X-ray tube.

11. A device as claimed in claim 7, in which the cathode filament systems for the two X-ray tubes are mounted in a common casing.

12. A device as claimed in claim 11, in which said common casing is secured to mounting means which includes an X-ray target in alignment with the cathode filament for said second X-ray tube and a side window through which X-rays from said target are beamed.

13. A device as claimed in claim 12, which includes a protecting tube for the anode tube, said protecting tube being displaceable relative to the housing and in the

axial direction of the anode tube in such manner that in a first, extended position it encloses the anode tube while in a second, withdrawn position the anode tube projects outwardly through an aperture provided in the protecting tube, and wherein windows for the outward transmission of X-rays from said X-ray target are provided in said housing and in said protecting tube at positions such that the windows are aligned with said side window when the protecting tube is in said first position enclosing the anode tube.

14. A device as claimed in claim 13, in which the protecting tube permits radiation to be transmitted only from that X-ray tube which is operational.

15. A device as claimed in any preceding claim, in which said casing of the hollow-anode X-ray tube including the part of the anode tube adjacent to the cathode is formed from a ceramic material.

16. A device as claimed in any of claims 7 to 14, in which the casing of said second X-ray tube is formed from a ceramic material.

17. A device as claimed in claim 15 or 16, in which the ceramic material is an oxide.

18. A device as claimed in any preceding claim, wherein the material at the head of the anode tube containing the anode and which effects a filtering of the radiation from the tube is such that uniform filtering of the radiation occurs over a predetermined beam angle.

19. A device as claimed in claim 18, in which the wall thickness at the head of the anode tube is non-uniform and is such that all X-rays emitted into said beam angle traverse equal length paths through the tube wall.

20. A device as claimed in claim 18, in which additional filtering material is provided at the head of the anode tube as an addition to the basic material of the tube, the additional material being distributed such that the X-rays which on account of their angle of emission traverse a shorter path length through the tube wall pass through a greater mass of filtering material than the X-rays which traverse a longer path length.

21. A device as claimed in claim 20, in which the wall of the head of the anode tube is cylindrical and of uniform thickness.

22. A device as claimed in claim 20, in which the additional filtering material is provided on an applicator tube which is displaceable about and relative to the anode tube.

23. A device as claimed in claim 20, in which the additional filtering material is provided partially on the head of the anode tube and partially on an applicator tube displaceable about and relative to the anode tube.

24. A device for use in producing X-ray photographs, substantially as hereinbefore described with reference to Figs. 1 and 2, Fig. 3, Figs. 6 and 7, Figs. 8 and 9, or any of these Figures when modified in accordance with Fig. 4B or Fig. 5 of the accompanying drawings.

25. A dental X-ray device comprising a device for the production of X-ray photographs as claimed in any preceding claim.

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3 SHEETS

COMPLETE SPECIFICATION

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SHEET 1

Fig.1

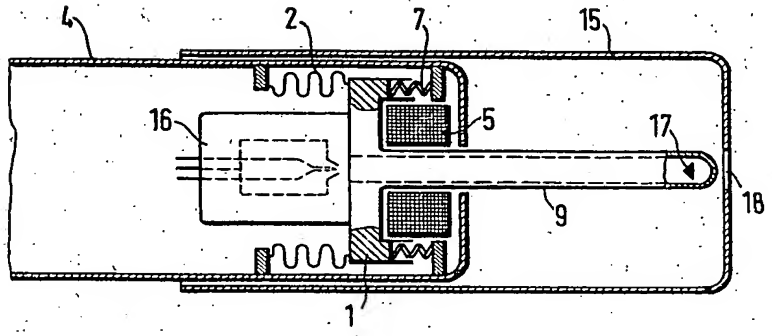


Fig.2

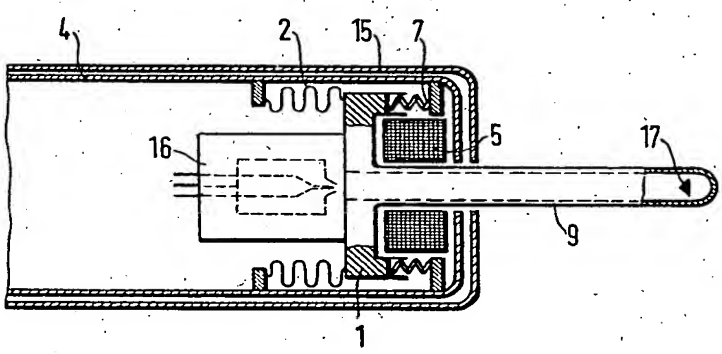


Fig.3

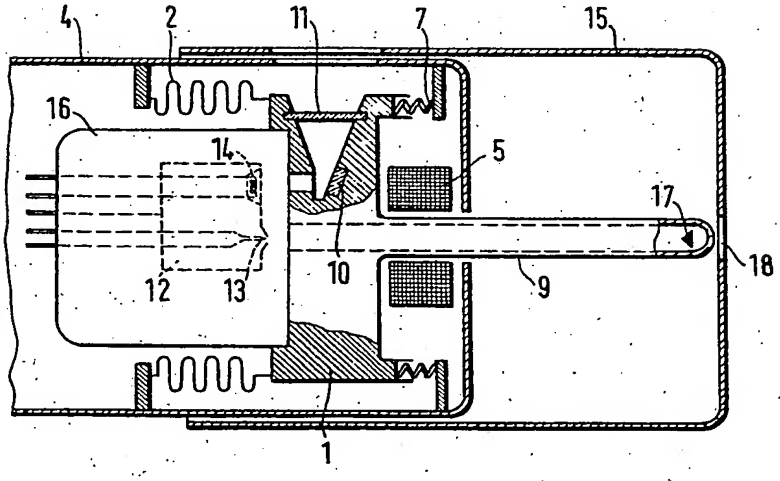


Fig.4

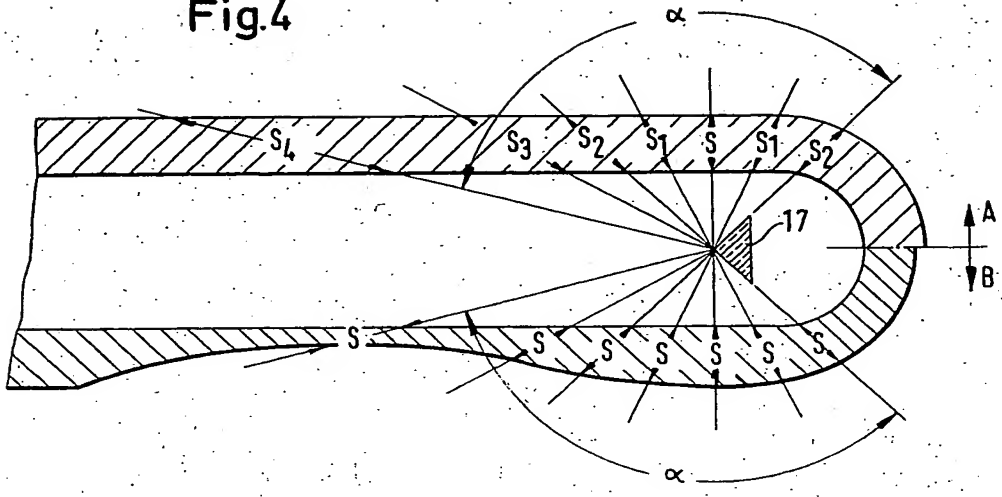
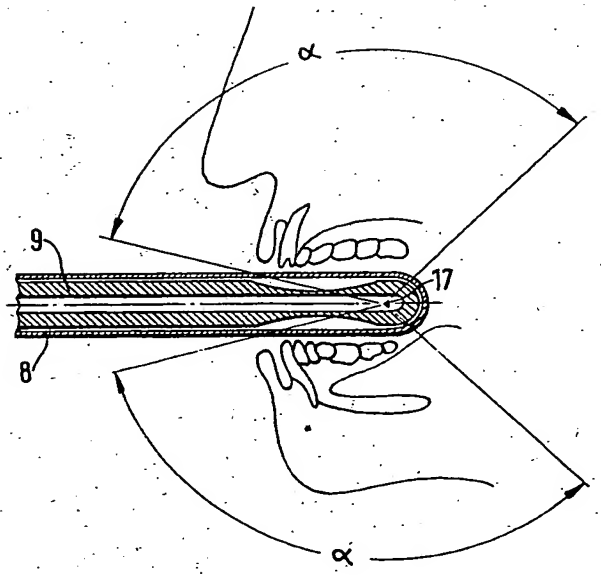


Fig.5



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SHEET 3

Fig.7

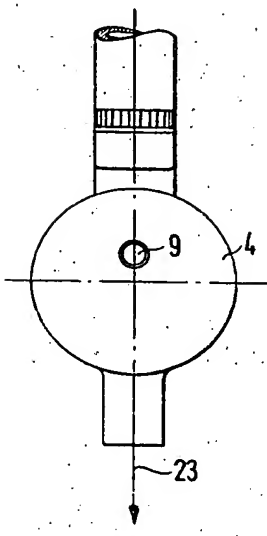
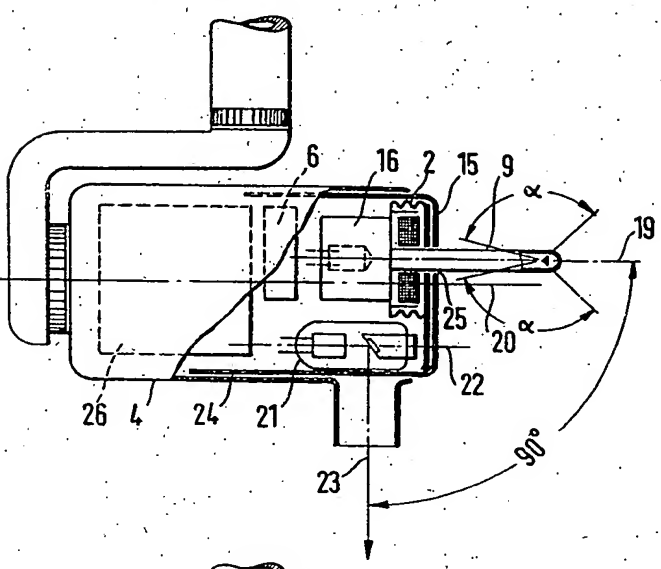


Fig.6



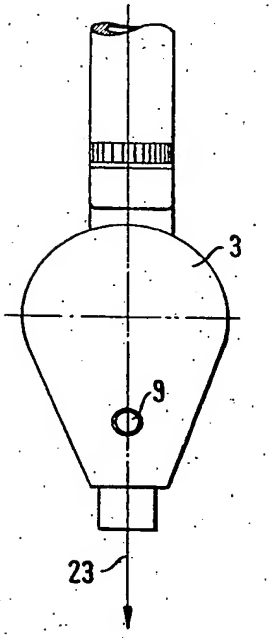


Fig.9

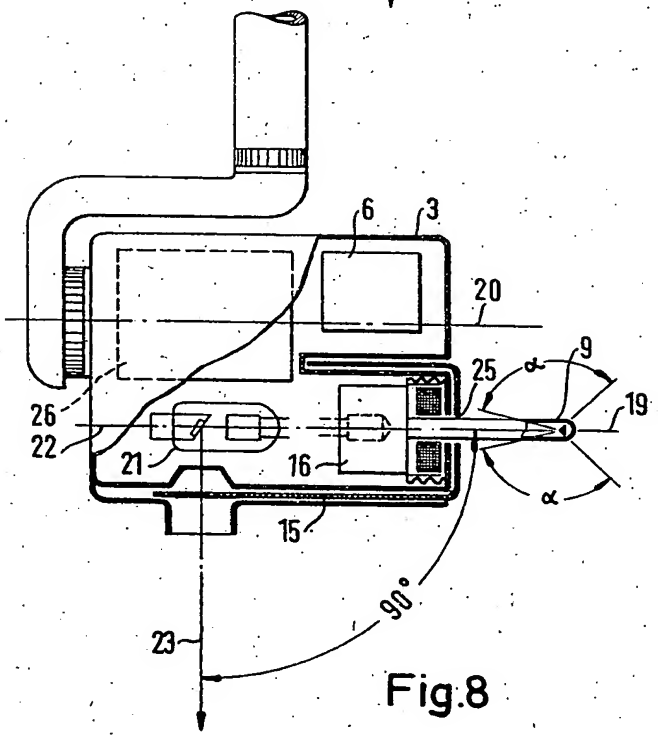


Fig.8